Combining Interictal and Ictal Low-Density EEG Source Imaging to Delineate the Epileptogenic Zone in Young Children

Roberto Santalucia[1,2]*, Carlotta Carosio[3], Antonio Giulio Gennari[3], Amir Ghasemi Baroumand[4], Pascal Vrielynck[1], Alexane Fierain[1], Antoine Guilmot[1], Vincent Joris[1,2], Susana Ferrao Santos[1,2], Enrique Germany Morrison[2], Pieter van Mierlo[4], Georgia Ramantani[3], Riëm El Tahry[1,2]

[1]Center for Refractory Epilepsy, Cliniques universitaires Saint-Luc, Brussels; [2]Institute of Neurosciences, UCLouvain, Brussels; [3]University Children's Hospital Zurich; [4]Clouds of Care NV, Ghent *roberto.santalucia@saintluc.uclouvain.be

Introduction and objectives

- The utility of low-density EEG source imaging (LD-ESI) in young children with drug-resistant epilepsy (DRE) remains unclear. We retrospectively analyzed children <7 years undergoing resective surgery to evaluate interictal (IIC) and ictal (IC) ESI feasibility, sublobar accuracy in localizing the epileptogenic zone, and predictive value for postoperative seizure freedom.

Methods

- Data from consecutive children meeting the inclusion criteria who underwent resective surgery at two centers (Jan 2015-Jun 2022) were reviewed.
- IIC-ESI: De-identified LD-EEG and MRI data were automatically processed with Persyst ESI, blinded to clinical data. Up to four spike clusters were analyzed at half-rise and peak; localizations were validated in ad hoc MDT meeting, with added value defined as the percentage of ESI-driven virtual plan modifications.
- IC-ESI: Two investigators manually marked seizure onset. ESI was computed using a sliding window approach, within a -2 to +2 sec time frame relative to seizure onset, with three overlapping 2-sec windows. Selection criteria per seizure et per seizure type (with a cut-off ≥ 75%) were applied.
- ESI results were classified as concordant (within resection cavity) or discordant (outside) at the sublobar level. Outcomes were dichotomized as seizure-free (SF) or not (NSF) per ILAE classification.
- Diagnostic accuracy and odds ratio (DOR) were assessed for IIC and IC-ESI separately and for the combined approach, where both techniques were used in parallel. Subgroup analysis and multivariate logistic regression were performed.

Results

Study population (n=32):

- Gender: 21 ♂ and 11 ♀; ratio 1,9:1
- Mean age at surgery: 45.53 ± 22.64 m.
- Mean epilepsy duration: 24.34 ± 18.41 m.
- Cognition: 13 (40%) ID/GDD
- Seizure type: multiple in 28 (87,5%), FIC and FPC most frequent, TS in 15 (47%) and ES in 7 (22%); NR pattern in 9 (28%)
- Epilepsy type: focal (40%), multifocal (47%), DEE (13%); extra-temporal or temporal « plus » (78%)
- MRI lesion: single in 24 (75%), multiple in 7 (22%), and negative in 1 (3%)
- Surgical resection: limited in 25 (78%), extensive in 7 (22%)
- Aetiology: MCD and LEATs (70%)
- Outcome: 21 SF (66%) and 11 NSF (34%) with mean follow-up of 53,47 ± 28,68 months

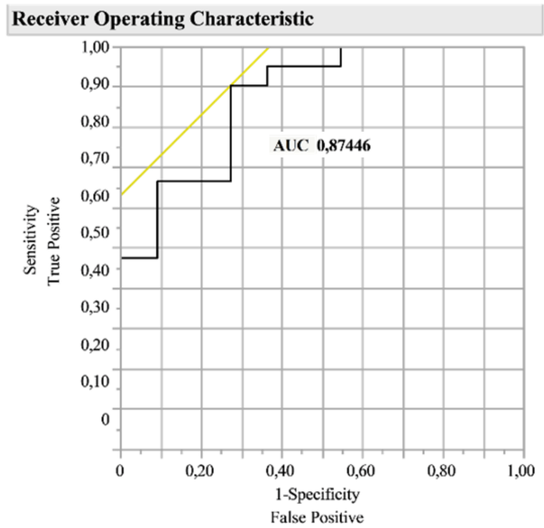
	Sensitivity	Specificity	Accuracy	PPV	NPV	LR+	LR-	DOR
IIC-ESI	71% (48-89%)	55% (23-83%)	66% (47-81%)	75% (60-86%)	50% (30-70%)	1,57 (0,78-3,17)	0,52 (0,22-1,24)	3 (0,66 -13,69) p = 0,15
IC-ESI	86% (64-97%)	45% (17-77%)	72% (53-86%)	75% (63-84%)	62% (33-85%)	1,57 (0,89-2,77)	0,31 (0,09-1,08)	5 (0,91-27,47) p = 0.06
Combined IIC/IC-ESI	95% (76-99%)	36% (11-69%)	75% (56-88%)	74% (64-81%)	80% (33-97%)	1,50 (0,95-2,36)	0,13 (0,02-1,03)	11,4 (1,08-120,35) **p= 0,042**

Subgroup	IIC-ESI accuracy	IC-ESI accuracy	IIC-ESI DOR	IC-ESI DOR
NR seizure pattern (n = 9)	77.78% (40-97%)	44.44% (14-79%)	6 (0.18 -196.29) p = 0.31	0.25 (0.01-7.27) p = 0.42
Multifocal/DEE (n = 19)	52.63% (29-75%)	73.68% (49-91%)	1.33 (0.20-8.70) p = 0.76	8.25 (0.65-104.19) p = 0.1
MCD/tumour (n = 22)	77.27% (55-92%)	86.36% (65-97%)	15 (1.32-169.87) **p = 0.028**	35 (2.57-475.33) **p = 0.0076**
Other aetiologies (n =10)	40.00% (12-74%)	40.00% (12-74%)	0.37 (0.02-6.35) p = 0.49	0.27 (0.009-8.46) p = 0.45

ID/GDD: intellectual deficiency/global developmental delay; FIC: focal impaired consciousness; FPC: focal preserved consciousness; TS: tonic seizures; ES: epileptic spasms; NR: non-rhythmical; DEE: developmental and epileptic encephalopathy; MCD: malformation of cortical development; LEATs: low-grade epilepsy associated tumors

Parameter Estimates

Term	Estimate	Std Error	Chi-Square	Prob>Chi-Sq
Intercept	-1,6641105	1,6985318	0,96	0,3272
Epilepsy duration (months)	0,03953523	0,0566562	0,49	0,4853
ID/GDD (Yes or Not) [Not]	1,2796151	0,6874559	3,46	0,0627
Seizure pattern (R vs NR) [R]	1,56840615	1,1053348	2,01	0,1559
Type of Epilepsy (F vs MF/DEE) [F]	-0,4025518	0,5993465	0,45	0,5018
Surgery (Lim vs Ext) [Ext]	0,36212562	0,6297949	0,33	0,5653
Etiology (MCD/T vs O) [MCD/T]	1,72867783	1,0647514	2,64	0,1045
Combined IIC/IC ESI [Positive]	-2,701988	1,2154426	4,94	0,0262*



Conclusions

- Combined LD-IIC- and IC-ESI is feasible in children under 7 and yields clinically meaningful accuracy in delineating the EZ. The approach also shows strong potential to predict seizure outcome.
- IIC- and IC-ESI provide complementary insights, and their relative contribution may help tailor diagnostic priorities to the individual clinical scenario.
- The current results support a broader integration of ESI in presurgical workflows for young children with DRE, a population that is particularly likely to benefit from accessible, non-invasive diagnostic techniques that can help avoid delays and reduce reliance on more invasive or resource-intensive procedures. By supporting earlier and more targeted surgical intervention, ESI may ultimately contribute to improved postsurgical seizure control.